Gowin ISP System

User Manual

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Revision History

Date	Version	Description
7/20/2021	1.0E	Initial version published.
08/27/2021	1.01E	The description of system resource updated and the max. frequency information added.

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1 About This Guide

1.1 Purpose

- ISP overview
- ISP module description
- ISP application reference designs

1.2 Related Documents

You can find the related documents at www.gowinsemi.com:

- IPUG782, Gowin AEAWB IP User Guide
- IPUG757, Gowin Color Filter Array Interpolation IP User Guide
- IPUG766, Gowin Color Correction Matrix IP User Guide
- IPUG765, Gowin Gamma Correction IP User Guide
- IPUG769, Gowin Video Frame Buffer IP User Guide
- IPUG902, Gowin CSC IP User Guide
- IPUG903, Gowin Scaler IP User Guide

1.3 Support and Feedback

Gowin Semiconductor provides customers with comprehensive technical support. If you have any questions, comments, or suggestions, please feel free to contact us directly using the information presented below.

Website: www.gowinsemi.com

E-mail: support@gowinsemi.com

1.4 Terminology and Abbreviations

Table 1-1 shows the abbreviations and terminology used in this manual.

Table 1-1 Terminology and Abbreviations

Terminology and Abbreviations	Full Name
ISP	Image Signal Processing
CFA	Color Filter Array Interpolation
CCM	Color Correction Matrix
CSC	Color Space Conversion
BLC	Black Level Correction
DPC	Defect Pixel Correction
AE	Auto Exposure
AWB	Auto White Balance

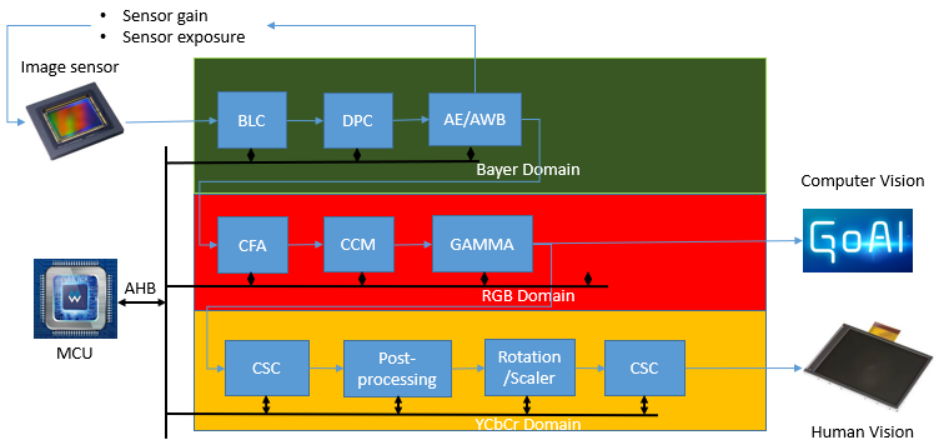
2 ISP Overview

2.1 Structure

Image Signal Processing (ISP) is used to process the output signal of the front-end Image sensor. In reality, due to the physical defects of the lens and sensor, as well as the need for the sensor to adapt to different light environments, it is necessary for the ISP to control the sensor and process the image signal, so as to obtain the expected image quality.

Figure 2-1 shows the typical and reduced ISP structure.

Figure 2-1 Typical and Reduced ISP Structure

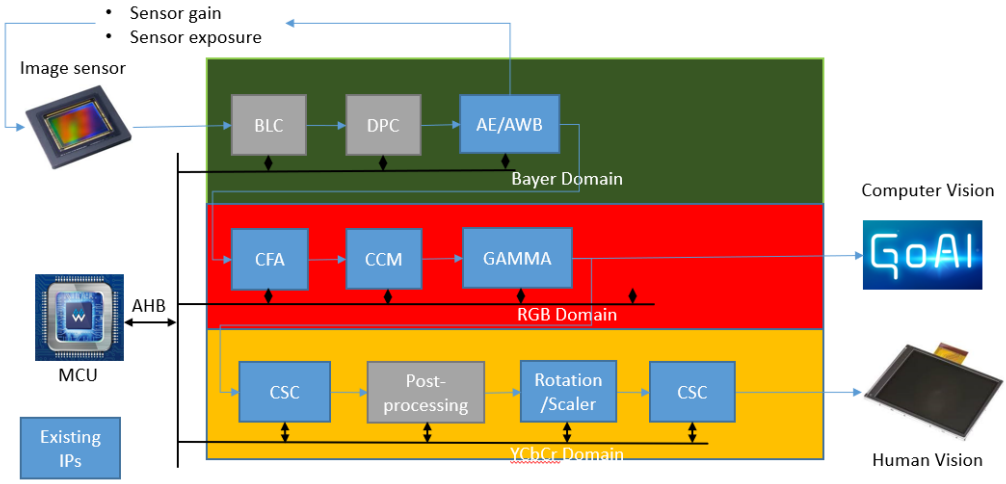


- BLC: Black Level Correction
- DPC: Defect Pixel Correction
- AE: Auto Exposure
- AWB: Auto White Balance
- CFA: Color Filter Array Interpolation
- CCM: Color Correction Matrix
- GAMMA: GAMMA Correction

- CSC: Color Space Conversion
- Scaler: Scaling module

Currently, the ISP project system is designed to implement the main ISP blue modules, as shown in Figure 2-2. If you need to design the gray modules, you can contact the relevant technical personnel of Gowin.

Figure 2-2 ISP System Design



2.2 Features

- Supports 4 types of sensor alignments (BGGR, GBRG, GRBG, RGGB), and 8bit/10bit image data.
- Support all kinds of image resolution (VGA, 720p, 1080p, 2K, 4K).
- Independent ISP sub-blocks, including”
  - AEAWB: Automatically adjusts the white balance and exposure.
  - CFA: Converts the Bayer's image to RGB image.
  - CCM: Achieves color correction.
  - GAMMA: Achieves non-linear operations on the image gray value.
  - CCM: Achieves color space conversion.
  - Scaler: Achieves image scaling.

2.3 System Resource

ISP Demo allows for the processing of 1080p 30fps 8bit image data in real time. Its resource is as listed in Table 2-1. ISP module resource is as listed in Table 2-2.

Table 2-1 ISP Demo Resource

Module	Register	LUT	ALU	DSP	BSRAM	SSRAM	PLL
Ov5647 Initialization	225	462	31	0	0	0	0
MIPI CSI-2 Interface	448	444	41	0	1	17	0
FOV Cropping	42	60	0	0	0	0	0
ISP Pipeline	2722	2013	1441	12	10	16	0
Video Frame Buffer	346	684	86	0	8	0	0
DDR3 Memory Interface	1729	1399	61	0	8	70	0
Scaler	892	623	68	0	18	4	0
Other	119	119	4	0	0	0	3
M1	2490	5694	162	3	64	20	0
Total	9165	11636	1894	13	109	131	3

Table 2-2 ISP Module Resource

Module	Register	LUT	ALU	DSP	BSRAM	SSRAM
CFA	597	570	693	0	6	0
CCM	578	56	0	6	0	0
GAMMA	76	22	0	0	1	0
AEAWB	1238	1153	748	6	3	4

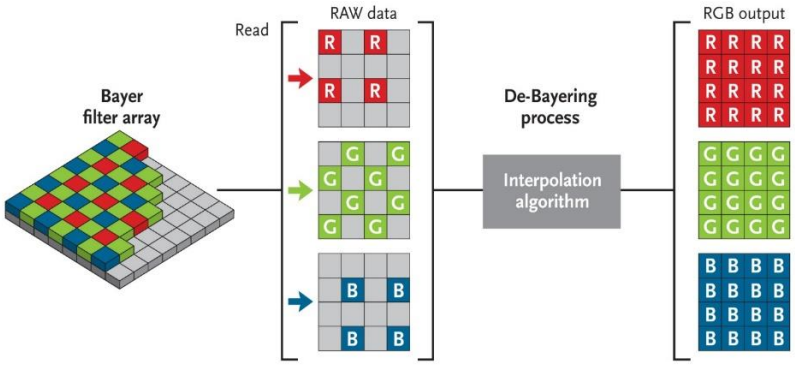
2.4 Max. Frequency

The maximum frequency of ISP Demo depends on the speed grade of the devices. Up to 90M can be supported.

3 ISP System Module

3.1 CFA

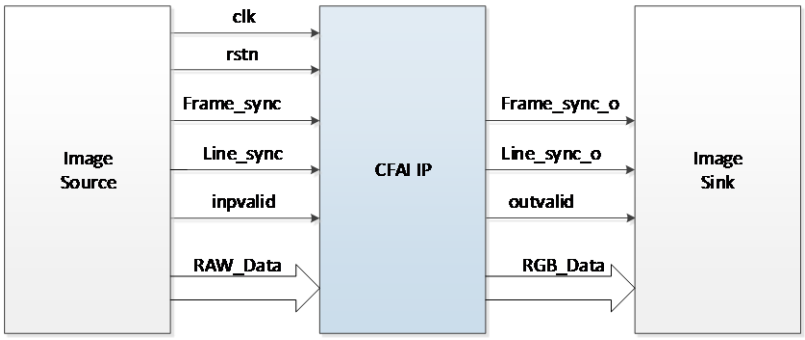
Figure 3-1 CFA Module



According to the characteristics of interpolation filter coefficients, Gowin Color Filter Array Interpolation IP is optimized for different sensor array modes and uses 5x5 high-quality operator. Different filter coefficients are used in R, G, B interpolation depending on the position of the missing value.

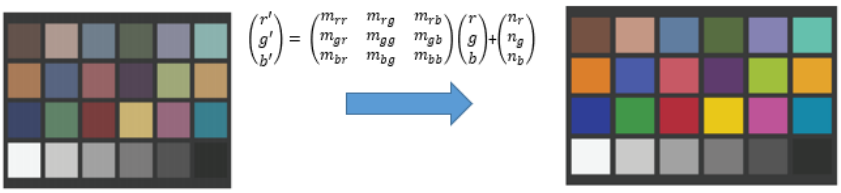
The module ports are shown in Figure 3-2.

Figure 3-2 CFA Module Ports



3.2 CCM

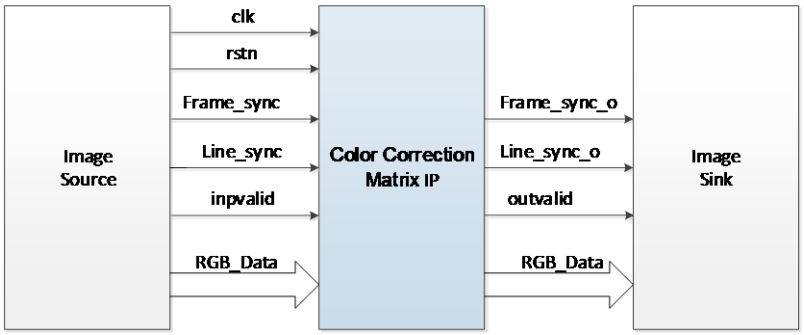
Figure 3-3 CCM Module



CCM is the color correction matrix. CCM is to correct the color error caused by the color penetration between the color blocks at the filter plate, so that the mapped color is more in line with the human perception. The color correction matrix is calculated by comparing the image captured by the image sensor with a standard image. This matrix is the color correction matrix (CCM) of the image sensor. In the application of the image sensor, this matrix can be used to correct all the images taken by the image sensor to obtain the images closest to the real color of the objects.

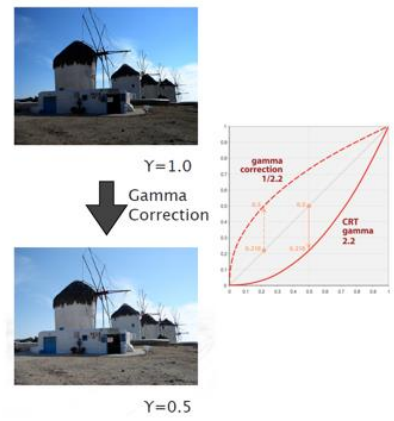
The module ports are shown in Figure 3-4.

Figure 3-4 CCM Module Ports



3.3 GAMMA

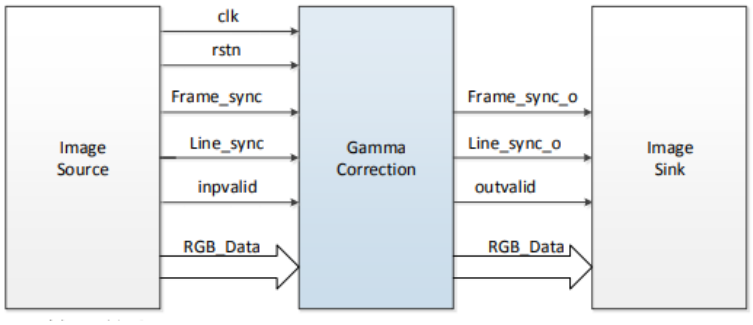
Figure 3-5 GAMMA Module



Gamma Correction is an algorithm that exponentially changes the input image grayscale values to correct brightness deviations. There is an exponential relationship between the light intensity of external light sources and the input light intensity. That is, at low illumination, it is easier for the human eye to distinguish changes in brightness. With the increased illumination, the human eyes are less likely to distinguish changes in brightness. There is a linear relationship between the camera photo sensitivity and input light intensity. In order to facilitate the human eyes to recognize the image, the images captured by the image need gamma correction.

The module ports are shown in Figure 3-6.

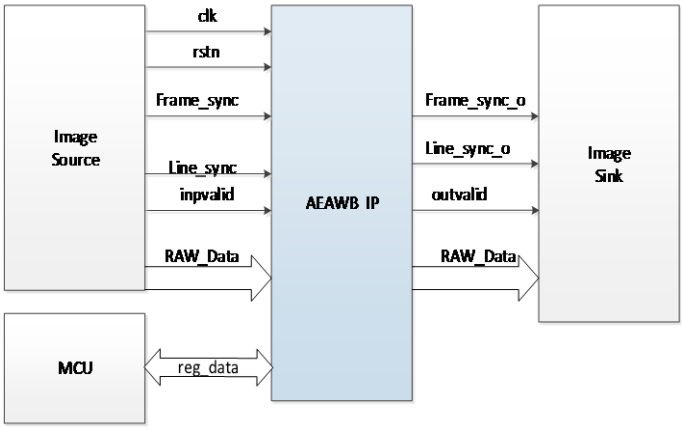
Figure 3-6 GAMMA Module Ports



3.4 AEAWB

AEAWB, or auto exposure/auto white balance. It is used to adjust image exposure and white balance according to statistical image information. The module ports are shown in Figure 3-7.

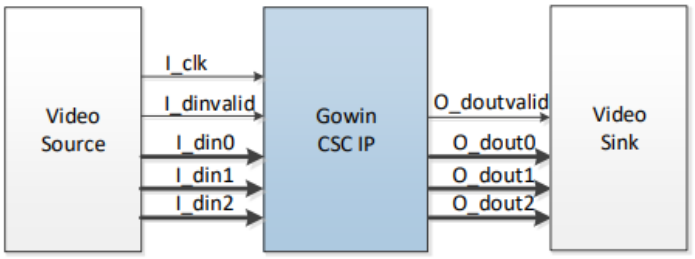
Figure 3-7 AEAWB Module Ports



3.5 CSC

Gowin CSC (Color Space Convertor) IP is used to realize different three-axis coordinates color space (RGB，YIQ、YCbCr) conversion, such as the common conversion between YCbCr and RGB. The module ports are shown in Figure 3-8.

Figure 3-8 CSC Module Ports

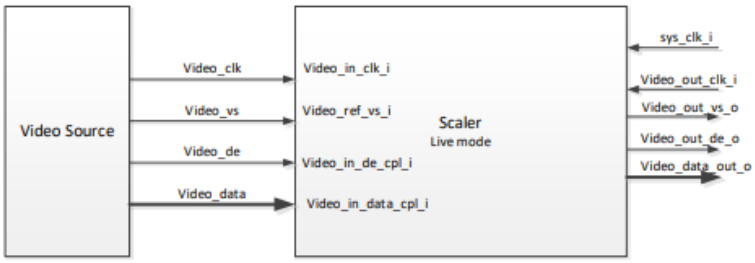


3.6 Scaler

Gowin Scaler IP is used to convert the input video images from one resolution Xin * Yin to another output resolution Xout * Yout. Resolution parameters can be preset in the IP configuration interface or dynamically configured in real time. In addition, interpolation algorithms supported by Scaler IP include nearest neighbor, bilinear and bicubic.

The module ports are shown in Figure 3-9.

Figure 3-9 Scaler Module Ports



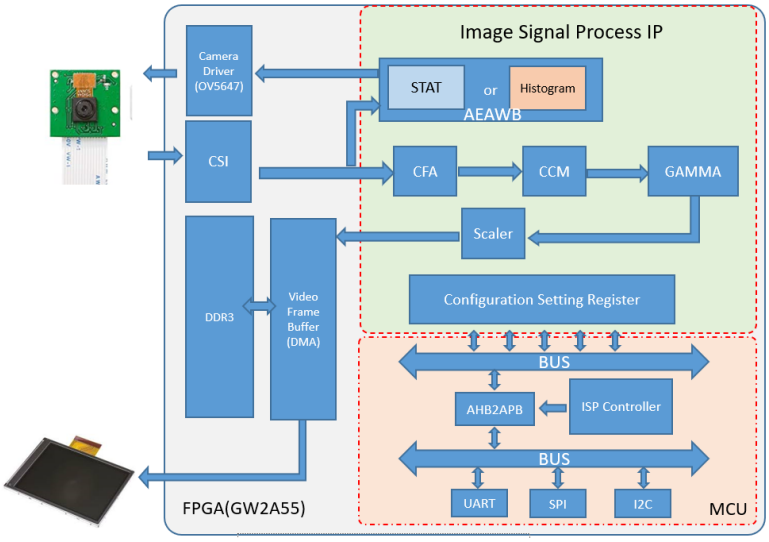
4 ISP Application Reference Designs

4.1 Hardware Platform Used by the Demo Design

- ISP Demo adopts the development board of DK_START_GW2A55-PG484.
- FPGA part mainly realizes the functions of image sensor driver control, CSI data reception, ISP image signal processing, DDR3 image storage, and LCD driver display.
- MCU is realized by the FPGA's soft core of Cortex-M1. MCU realizes instruction control and display through data communication between UART and PC. After that, data instruction realizes the register reading and writing of ISP module through the AHB bus of MCU.
- The image sensor model is OV5647, which is connected through the CSI interface of FPGA to realize the control and data communication.
- The LCD model AT070TN94, which is connected through the LCD interface of FPGA to achieve image display.

4.2 Demo Structure

Figure 4-1 Demo Structure



FPGA Part

The FPGA part is mainly used to control the image sensor through the drive module to obtain the 1080p image, and then the ISP module accepts and processes the 1080p image, the Scaler module scales the size of the LCD image, and finally the LCD displays the image.

- Camera Driver: Achieves the driver control of the image sensor.
- CSI: Receives and identifies the data from the sensor CSI.
- CFA: Converts the Bayer's image from the sensor to RGB image.
- CCM: Performs color correction on RGB images.
- GAMMA: Performs GAMMA correction on the image to make it meet the sensitivity of human eyes to light and dark.
- AEAWB: Performs data statistics and histogram statistics on the Bayer images. Adjusts the white balance according to the data statistics and adjusts the exposure according to the histogram statistics.
- Scaler: Achieves image scaling.
- Video Frame Buffer: Controls DDR3 reading and writing images.
- DDR3: Stores each frame of image data.

MCU Part

The MCU part is mainly used to achieve PC command control, FPGA data communication, and AE and AWB debug control.

- PC command control: Communicates with PC through UART. Whenever the UART terminal sends instructions, the UART of MCU

interrupts and responds to complete the operation of receiving, identifying and sending instructions.

- FPGA data communication: Controls the reading and writing operations of the ISP register through the internal AHB parallel bus.
- AE and AWB debug control: By reading statistics and histogram information of ISP module, dynamically adjusts and controls the AE and AWB image sensor to form a closed-loop control

4.3 MCU Command Control

1. During initialization, the soft core Cortex-M1 in the FPGA will print the relevant initialization information via UART.

2. Command control: The command format is sent to FPGA soft core Cortex-M1 through UART for related control.
   - Command format: address (12bit) + data (32bit) + #(closing symbol).
   - The address and data are entered as hexadecimal numbers, separated by a space symbol.
   - Example: If the AWB register value is set to 0x4FF, the command is "0x104 0x4FF #".
   - Register reading and writing operations are as listed in Table 4-1.

Table 4-1 Register Reading and Writing Operations

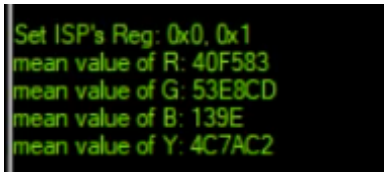
	Name	Address	Data	W/R	Default	Note:
ISP						
1	ISP_CMD	0x000	[3:0]	W	-	ISP command 4'b0001 --- show current mean value 4'b0010 --- show current histogram

	Name	Address	Data	W/R	Default	Note:
						value 4'b0011 --- AWB processing 4'b0100 --- AE processing
2	ISP_REG_LOAD	0x004	[15:0]	W	-	Load reg's value from module
3	ISP_REG_GET	0x008		R		Get reg's value
Sensor						
1	CAM_AWB_EN	0x100	[0]	W	0x1	Sensor(Camera) AWB enable (0: Camera Auto enable ; 1: Manual enable)
2	CAM_AWB_R	0x104	[15:0]	W	0x0400	Sensor(Camera) AWB R gain value
3	CAM_AWB_G	0x108	[15:0]	W	0x0400	Sensor(Camera) AWB G gain value
4	CAM_AWB_B	0x10C	[15:0]	W	0x0400	Sensor(Camera) AWB B gain value
5	CAM_AGC_EN	0x110	[0]	W	0x1	Sensor(Camera) AGC manual enable (0: Camera Auto enable ; 1: Manual enable)
6	CAM_AGC_GAIN	0x114	[15:0]	W	0xFF	Sensor(Camera) AGC gain value
7	CAM_AEC_EN	0x118	[0]	W	0x1	Sensor(Camera) AEC manual enable (0: camera Auto enable ; 1: Manual enable)
8	CAM_EXPOSURE	0x11C	[19:0]	W	0x20	Sensor(Camera) AEC Exposure
CCM						
1	CCM_K11	0x200	[31:0]	W	0x0000142C	K11
2	CCM_K12	0x204	[31:0]	W	0xFFFFFC4C	K12

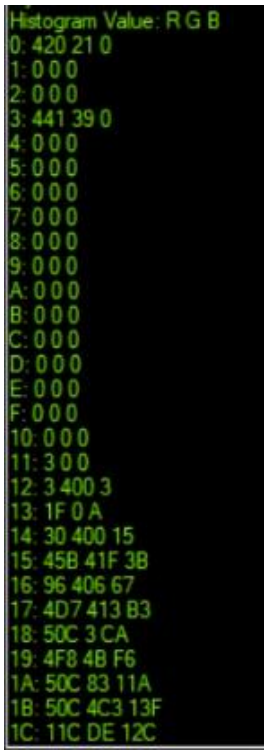
	Name	Address	Data	W/R	Default	Note:
3	CCM_K13	0x208	[31:0]	W	0x000001A5	K13
4	CCM_K21	0x20C	[31:0]	W	0xFFFFFF89	K21
5	CCM_K22	0x210	[31:0]	W	0x000015B5	K22
6	CCM_K23	0x214	[31:0]	W	0xFFFFF760	K23
7	CCM_K31	0x218	[31:0]	W	0x00000108	K31
8	CCM_K32	0x21C	[31:0]	W	0x000000D9	K32
9	CCM_K33	0x220	[31:0]	W	0x000019B7	K33
10	CCM_O1	0x224	[31:0]	W	0xFF7AF699	O1
11	CCM_O2	0x228	[31:0]	W	0xFF7576A4	O2
12	CCM_O3	0x22C	[31:0]	W	0xFF7D23A3	O3
AEAWB						
	AEAWB_GET_ AWB_GAIN_R	0x410	[31:0]	R		Get AWB_GAIN_1
2	AEAWB_GET_ AWB_GAIN_G	0x414	[31:0]	R		Get AWB_GAIN_2
3	AEAWB_GET_ AWB_GAIN_B	0x418	[31:0]	R		Get AWB_GAIN_3
4	AEAWB_ MEAN_R	0x420	[31:0]	R		MEAN_R
5	AEAWB_ MEAN_G	0x424	[31:0]	R		MEAN_G
6	AEAWB_ MEAN_B	0x428	[31:0]	R		MEAN_B
7	AEAWB_ MEAN_Y	0x42C	[31:0]	R		MEAN_Y
8	AEAWB_SET_ EXPOSURE	0x44C	[31:0]	W		Set the exposure to the MCU
9	AEAWB_HISTO_ RDY_GET	0x460	[0]	R		Histogram is ready to read
10	AEAWB_HISTO_ RGB_GET	0x500	[29:0]x256	R	-	Load histogram RGB value Each RGB with 10bit in FPGA 's address from 0x500 to 0x5FF

3. The following command control can be achieved through the UART terminal.

   - The command to read the average data of the image RGB: “ 0x000 0x01 # ”

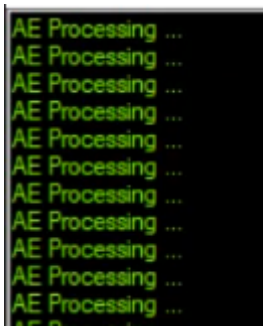
   - The command to read the histogram data of the image RGB: “ 0x000 0x02 # ”

   - The command to adjust AWB (Auto White Balance): “ 0x000 0x03 # ”; If you enter the same command again, the automatic white balance processing will stop.

- The command to adjust AE (Auto Exposure): “ 0x00 0x04 # ”; If you enter the same command again, the automatic exposure processing will stop.



- The command to write to registers of image sensor: “0x1XX 0xXX #”.
- The command to write to CCM registers of ISP: “0x2XX 0xXX #”.
- The command to write to exposure registers: “0x44C 0xXX #”.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